WASTE AND LABOR PRODUCTIVITY IN PRODUCTION PLANNING CASE FINNISH CONSTRUCTION INDUSTRY

Anssi Koskenvesa[1], Lauri Koskela[2], Teuvo Tolonen[3], and Satu Sahlstedt[4]

ABSTRACT

The main objective of this paper is to examine labor productivity and waste and their role in production planning and control in Finnish construction industry. Three hypothesis are tested: (1) the assumption that labor productivity concerning different construction work disciplines has developed very little in the last 30 years; (2) the amount of waste has stayed on a constant high level on sites in the Finnish construction industry; and (3) labor productivity does not develop because the initial information included in the production plans includes also waste as an accepted phenomenon.

A trend analysis of construction labor productivity is conducted over the period 1975-2008. Labor productivity and waste are examined through data from sites and Ratu-research (Finnish Construction Production Data on work methods and work rates). The results are examined along with prior international research findings on construction labor productivity, waste and production planning processes.

Although the data and sites, as well as the Ratu-research material, are Finnish, the results are internationally applicable and can be utilized and connected to modern ways of working anywhere. Evaluation and considerations made in this paper are followed by further work.

KEY WORDS

Labor productivity, Waste, Production planning, Ratu-files, Work rates.

INTRODUCTION

The construction industry is a key activity in any economy. In Finland construction industry is responsible for about 10 % of the gross national product (GNP). In 2008 construction investments made up 60 % of all investments in Finland (Confederation of Finnish Construction Industries). Still as in many other countries also labor productivity in construction is low compared to other sectors of industry. As labor costs are high and a large part of the total costs of construction, labor productivity has gained a lot of attention (e.g. Jonsson, 2006; Rojas & Aramvareekul, 2003; Lutz & Gabrielsson, 2002).

Several researchers around the world have focused on the demand for an improved process-oriented activity in construction projects. (Koskela, 1992; Lahdenperä, 1995; Nylén, 1999; Ballard 2000; Lindfors, 2003; Osipova & Atkin, 2008; Vennström, 2008). Improvement in construction industry performance would

[1] Researcher, Tampere University of Technology, Tampere, Finland, koskenvesa@mittaviiva.fi
[2] Professor, The University of Salford, Salford, M5 4WT, UK, l.j.koskela@salford.ac.uk
[3] Professor, Tampere University of Technology, Tampere, Finland, teuvo.tolonen@tut.fi
[4] Researcher, Tampere University of Technology, Tampere, Finland, satu.sahlstedt@mittaviiva.fi

have a major economic impact. To speed up this change, a research project called TuoVa-project (Managing factors influencing productivity of construction work) was started in Finland.

In TuoVa-project the scope is on managing the continuously changing site production. The main targets are productivity, efficiency and waste of construction work and the possibilities to influence them through production management and leadership. Like Rojas and Aramvareekul (2003) state, management skills and manpower issues are the two areas with the greatest potential for affecting productivity performance.

In management one of the key factors is co-operation between different parties (e.g. Haugen, 1999). Good co-operation needs trust. We have to be able to rely on one another and production planning needs to be trustworthy. Although projects have a strong tendency for tight schedules, both the general contractor and the subcontractors include a variable amount of so-called acceptable waste – ”looseness” and ”tightness” in the cost calculations, as well as in the “schedule targets” (Salminen, 2005). If we want to manage truthfully and build more productively, we have to know where the waste is and how to control and decrease the amount of it.

TREND ANALYSIS ON DEVELOPMENT OF LABOR PRODUCTIVITY

A trend analysis was conducted to study the change in the labour productivity between 1975 and 2008. The research subjects were twelve randomly picked work contents common at construction sites. One of these contents is a task in the foundation phase, four belong to the framing phase of the project, two are connected to the supplementing structures and five are tasks in the interior phase. These twelve tasks (work disciplines) were analyzed through the data that has been collected in Ratu-research.

Throughout the years research scientists and co-operative construction companies have collected data using data sheets (collecting daily or weekly working hours), time study methods and activity sampling. Each work method has been studied at least once every decade, some more. In every study for each method there has been empirical data from at least ten sites. The amount of data used in our evaluations is collected from more than 600 activities on different sites.

Total work hours (wh) were calculated for all tasks from unit rates (wh/quantity). Development of labor productivity is shown in Figure 1 and its comparison to the volume of housing construction industry in Finland is in Figure 2.

According to Figure 1 the level of labor productivity has improved from the mid 70´s by approximately 1% per year. Lack of major improvement is not the case only in Finland. There has been very little reduction in labor input or the quality of work improved also in other countries (Bertelsen, 2003). For example during years 1963 to 1998 labor productivity within Swedish manufacturing industries improved by 2,9% per year, where as the construction sector has improved labor productivity by only 1,7% per year (Lutz & Gabrielsson, 2002). Teicholz (2001) concluded that labor productivity has continued to slowly decline (with a few exceptions) over the past 25-30 years.

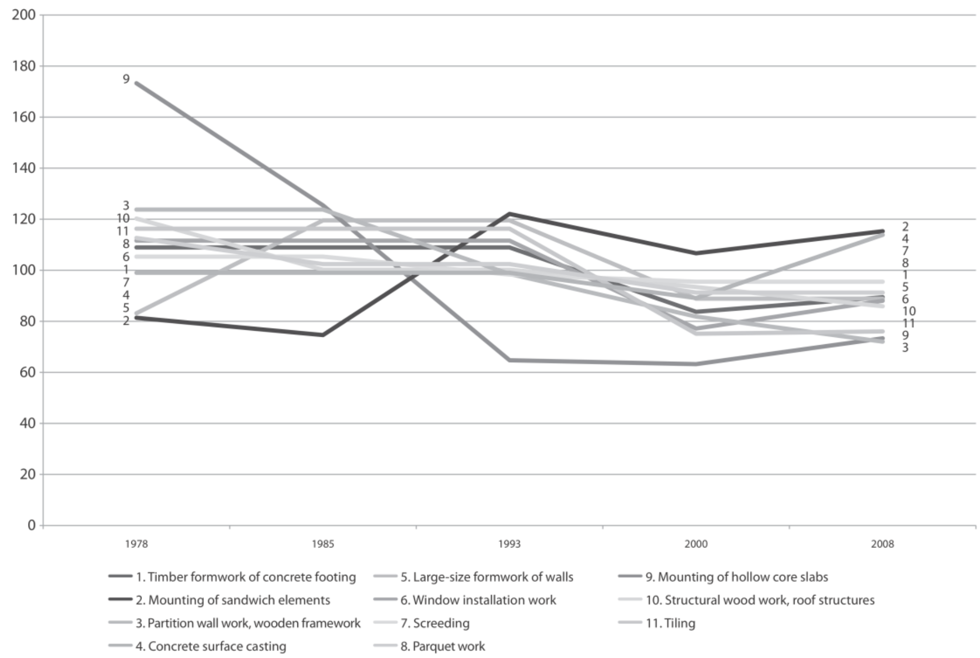

Figure 1. The development of labor productivity of twelve construction tasks between the years 1975-2008 in Finland

Figure 1 shows also that in three work disciplines (numbers 2, 3, 4 in Fig. 1) the development differs from the major group of work disciplines. These three are all from the framing phase.

The labor productivity of hollow slab mounting has improved significantly from the 1970´s. As Goodrum & Haas (2002) state development in material and equipment technology can explain increase in labor productivity. Major reason affecting the labor productivity development of hollow slab mounting are the improvements in the product and work methods as this form of prefabricated elements became more common in Finland in the 1980`s (Sorri-Teir & Hämäläinen, 1993).

As Figure 1 shows labor productivity in large-size formwork of walls and mounting sandwich elements has decreased. This is a phenomenon due to architecture and design with shorter walls, smaller pieces, more corners and more complex floor plans, etc. (Koskenvesa, 1989). Otherwise all of the work disciplines seem to follow the same pattern or trend.

As Figure 2 shows there has been one significant change. Labor productivity has increased in the mid 90´s, but has started to decrease again after 2000. From 1990-1994 Finland was in deep recession. Number of laborers in construction industry decreased dramatically as the volume of construction dropped more than 20 % every year (Ahti, 2009).

What happened during the recession in 1990-1994? New companies were founded and old ones bought by new owners. International companies came to Finnish markets and many companies were divided and ownerships rearranged. In the 1970´s and 80´s labor was mostly on the payrolls of the construction companies. During the recession only the best companies and crews stayed in business. After the recession subcontractors (old employees) did a lot of the work (Ahti, 2009).

This "new" way of organizing and the terms of contracts seem to have affected the labor productivity. As Abdel-Wahab et al. (2008) state productivity performance is changing over time in relation to its skills profile. Lower and higher skill level can explain variation in productivity performance (Clarke & Wall, 1996).

Figure 2. The development of the volume of house building projects (million m^3) in Finland (Ahti, 2009) compared with the average development of labor productivity (work hours) studied in TuoVa-project.

An example story of one project manager describes this development well:

" I could not manage to carry out a major sports hall project today (April 2008) as I did back in 1996. That is because I could not get the best subcontractors and the best crews of these subcontractors to work towards a mutual goal for the coming world championships like I did back then. Times were different. For a short while work was of great importance to everyone."

THE AMOUNT AND LEVEL OF WASTE

WASTE IN RATU-PRODUCTION FILES

In Finland a standardization project on production data started in 1973 following the Swedish example (Method och Data, 1967-1973). This project resulted to national production files – a general data collection of work methods and work rates for different kinds of construction works and trades (Ahokas & Kiiras, 1976). This Ratu-"database" (Finnish Construction Production Data on work methods and work rates) is still being updated after 35 years.

Ratu-data is mostly used for production planning (method and task planning, time-scheduling, procurement planning and cost estimating) and to provide information of construction works on quality, safety, environment etc. Data is also used for education, training and developing work methods.

Ratu-data consists of work contents and elements that are analyzed to understand the different variables (method, technical solutions, circumstances, etc.). The standard times for every work content are tested with empirical data from at least ten sites every five to eight years. By this testing the database is set to the common average level (Koskenvesa, 1989).

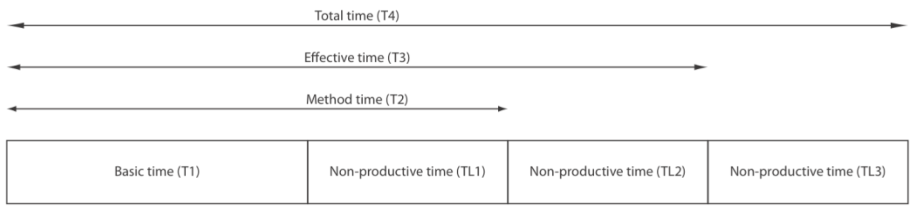

Figure 3. The terminology of work time used in presenting production data according to the Finnish Ratu-database

Ratu-standards (Fig 3) accept non-value adding time. The unit times are expressed as effective time (T3, work shift time) and as total time (T4). Effective time consists of method time (T2 ≈ optimal execution of a certain task with a certain method) and non-productive time (TL2 ≈ allowances and disruptions, which are considered “normal” and do not exceed one hour in length). Effective time (T3) is 10…20% more than method time (T2) and it is used in general work trade schedules, phase scheduling, task planning and weekly planning.

Table 1: TL3-percentage of twelve construction tasks (time reserved for allowances and disruptions that exceed one hour in length ≈ waste allowed in production data)

Work content / Year	1978	1985	1993	2000	2008
Timber formwork of concrete footing	20	20	20	20	15
Large-size formwork of walls	20	20	20	20	15
Mounting of hollow core slabs	10	10	10	10	20
Mounting of sandwich elements	20	20	20	10	20
Window installation work	10	20	20	5	10
Structural wood work, roof structures	20	20	20	7,5	15
Partition wall work, wooden framework	20	20	20	20	15
Screeding	10	10	10	20	20
Tiling	20	20	20	15	15
Concrete surface casting	20	20	20	15	20
Parquet work	20	20	20	15	15

Total time (T4 ≈ work phase time) includes all the expended hours including stops over one hour. T4 is used in cost estimation and preparing general schedules. Total time in Ratu-production data is and has been through the years mostly 10-30% more than the effective time (Table 1). No significant change has happened.

Like many studies around the world show the amount of waste in construction works is significant. Lee et al. (1999) show figures between 40-70% and both Christian & Hachey (1995) and Horman & Kenley (2005) state the waste to be around 50%. Also other studies show that 30% to 60% of time in construction is devoted to wasteful activities (e.g. Josephson & Saukkoriipi, 2005; Drewin, 1982). Ratu-production data includes 30-60% of waste (non-productive times TL2 and TL3) set on top of the method time. As methods include always some waste also, we can state that there is a significant amount of waste in our production data. The amount has also stayed on the same level for years as has TL2- and TL3-percentage (Table 1).

WASTE AS AN ACCEPTED PHENOMENON

Project plans and schedules are critical to the success of a project. According to the Project Management Body of Knowledge (PMBOK, 2000) planning is considered one of the main tasks of project management. When categorized roughly, three production planning and control systems are in use in Finland.

Normal custom is based to some extent on activity-based methods (CPM). Consciously or unconsciously, but these methods are widely used in some form and critical path is a common term used on sites. The main control methodology is to update plan with actual start and finish dates, estimating the remaining duration for ongoing tasks (Seppänen, 2009). Production flow, productivity and waste do not seem to be the issue. Secondly location-based scheduling called “Opas ja Turva” for production planning and control was developed in Finnish action research studies in the 1980´s (Kiiras, 1988). Third production control system used in Finland is Last Planner System™ (Ballard, 2000; Ballard and Howell, 2003). First Last Planner pilot projects in Finland took place in 2002 (Koskenvesa & Koskela, 2005). Since then LPS and the tools it presents have become more and more popular as they focus on the proactive control of the prerequisites of production instead of just control.

No matter how we plan and control planning needs data. Ratu-production files are one source of this data. According to Mäki (2008) in common practice four types of planning styles of schedules were found. Firstly, there is the “orthodox”-model where Ratu-productivity data is used in planning and controlling the schedules. Second category is the “buffer”-model, where Ratu-data is used, but a buffer is added inside each activity in contrast to the idea of “Opas ja Turva” (Kiiras, 1988) or Critical Chain Project Management (Stratton, 2009). Third type is the “subcontractor” – model, which relies on the information that the planner gets from each subcontractor. In this model there is a great possibility, but even bigger risk of getting the worst possible schedule if different trades reserve buffer time inside their task durations. Fourth model is very common “own estimation” where time frames and durations are estimated through experience of the planner.

In Figure 4 we can see four different cases which show how the planned differs from the actual work flow. In Figure 4a the start is 15 dates late. Work consists a lot of disturbances and still it gets done on time according to the task schedule - in other words a lot of waste inside the timeframe. In Figure 4b work goes smoothly until there is a disturbance. After that the work rate decreases. As Thomas & Zavrski (1999) state labor flow has been shown to be critical to productivity. The daily productivity of labor stays relatively constant in a project that does not experience disruptions. But like Figure 4c shows workspace congestion decreases productivity. We can prevent such congestion by better planning. But what is the data we plan according to? Figure 4d shows how the work is actually done 55 m^2/day when it is planned to be 35 m^2/day.

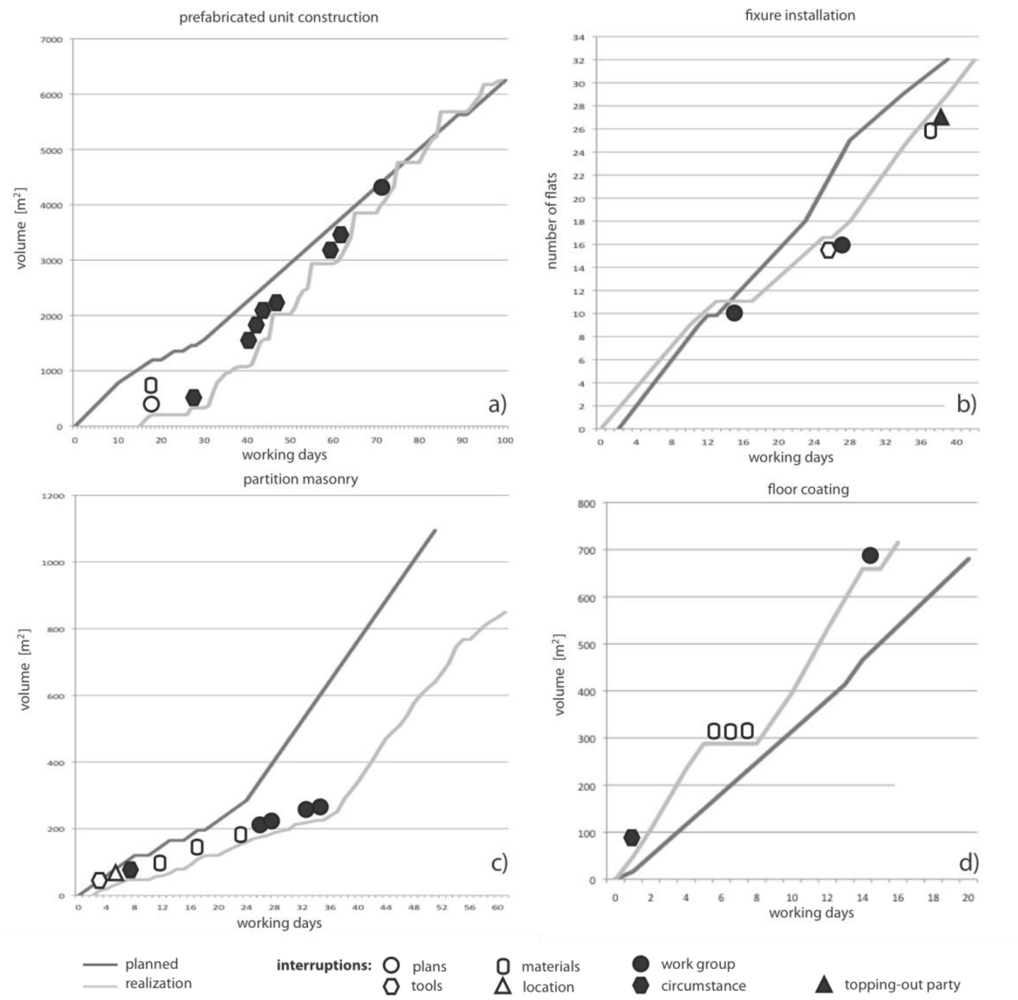

Figure 4. Planned and actual work flow on case construction sites (12/2009…4/2010)

It is important to keep schedules reliable. When the production is unreliable, the general contractor is motivated to demand too many resources, and the subcontractor is motivated to supply too few resources (Sacks & Harel, 2006). When production is more reliable, subcontractors have the motivation to allocate more resources, because they can maximize profits that way (Sacks, 2004). Pre-requisites for work have to be in order. Koskela (2004) states that the eight waste of “making-do” should be added to the seven wastes of Toyota Production Systems seven wastes (e.g. Womack & Jones, 1996; Liker, 2004). This refers to a situation where task is started without all its standard inputs or the execution of a task is continued although the availability of at least one standard input has ceased. Term input refers here not only to material, but to all other inputs such as machinery, tools, personnel, external conditions, designs, instructions etc. As Figures 4a and 4b show making-do as a waste has a great impact on the labor productivity of activities. This affects also interrelationships between trades. When a crew is late on delivering follow-on teams are prevented from starting when they are planned to. For high productivity, low waste and efficient production control, labor flow issues seem to be valid.

CONCLUSIONS

This paper concludes some of the results from the first phase of TuoVa-project.

The first hypothesis to be tested was that labor productivity has developed very little in the last 30 years. Our study shows that level of labor productivity has improved from the mid 70´s by approximately 1 % per year. Only significant improvement happened during and after the recession of 1990-1994. The shocking drop in the volume of construction industry led into a more labor productive phase. Main factor was the changes in project structures as more and more work was done by subcontractors and not by own employees. Figures 1 and 2 show how the influence of such development is not very long lasting. External factors like the economic situation can increase or decrease the labor productivity, but internal development in management practices, technology and labor skills and training are needed to make real changes (e.g. Lavender, 1996; Olomolaiye et al., 1998; Naoum, 2001).

The second hypothesis was that the amount of waste has stayed on a constant high level. The analysis on Ratu-data as well as the waste (non-productive time) accepted in effective time T3 and total time T4 show that waste in Finnish construction industry has been and still is on as high a level as the international literature indicates.

The third hypothesis stated that labor productivity does not develop because the initial information in production plans includes also waste as an accepted phenomenon. When “standards” like Ratu accept a great amount of waste (Table 1) and non-value adding activities, waste is also admitted in the schedules (Figure 4), task durations, contracts and cost estimations. Thus, waste is not paid a lot of attention to in the production planning or control processes.

Consequently there is considerable potential for improvement in construction through initiatives that reduce levels of wasteful activity. When trying to improve productivity and optimise production, it is important to consider all aspects of production (transformation, flow and value) and really manage production, not only the project (Koskela, 2000). The basic data used for planning needs to be reliable enough and methods for managing effective enough to be able to handle the constantly changing production environment on site. TuoVa-project continues in its future phases to work on how to manage the work sites more efficiently by improving productivity and minimizing waste.

REFERENCES

Abdel-Wahab, M., Dainty, A., Ison, S., Bowen, P. & Hazlehurst, G. (2008). “Trends of skills and productivity in the UK construction industry.” *Journal of Engineering, Construction, and Architecture Management*, 15(4), pp.372-382.

Ahokas, J. & Kiiras, J. (1976). “The preparation of production files for house construction.” *Main report, Research Notes 42*. Technical Research Centre of Finland, Laboratory of Building Economics, Espoo, Finland.

Ahti, A. (2009). “Rakennusalan taloustaantuman 2009-2012 vertailu talouslamaan 1990-1994.” *Rakentajain kalenteri 2010*, pp. 487-496. Helsinki, Finland.

Ballard, G. (2000). “The Last Planner System of production control”, *PhD thesis*, University of Birmingham, Birmingham, UK.

Ballard, G. and Howell, G. (2003). "An update on Last Planner”, *Proc., 11th IGLC Conference*, Blacksburg, VA.

Bertelsen, S. (2003). “Complexity – Construction in a New Perspective.” *Proceedings of the 11th Annual Conference of the IGLC*, Blacksburg, Virginia, USA.

Christian, J. & Hachey, D. 1995. “Effects of Delay Times on Production Rates.” *Journal of Construction Engineering and Management*, Vol. 121, (1), pp. 20-26

Clarke, L. & Wall, C. (1996). “Skills and the construction process.” *Housing Research Report*.

Drewin, F.J. (1982). Construction productivity. Elsevier Science Pub. N.Y., USA.

Goodrum, P. & Haas, T. (2002). “Partial Factor Productivity and Equipment Technology Change at Activity Level in U.S. Construction Industry.” *Journal of Construction Engineering and Management*. Volume 128, Issue 6, pp. 463-472.

Haugen, T. (1999). “The Building Process: challenges in a changing environment.” *Proceedings of the Nordic Seminar on Construction Economics and Organization*, Gothenburg, Sweden.

Horman, M. & Kenley, R. (2005) "Quantifying levels of wasted time in construction with meta-analysis.” *Journal of Construction Engineering and Management, ASCE*. 131, Issue 1, 52-61.

Josephson, P.-E., and Saukkoriipi, L. (2005). “Slöseri i byggprojekt – Behov av förändrat synsätt.” *FoU-Väst report 0507*, Gothenburg, Sweden

Jonsson, J. (2006) “Construction Site Productivity Measurements.” Luleå University of Technology, Division of Construction Management, Luleå, Sweden.

Kiiras, J. (1989) “Opas ja Turva.” (A schedule and resource planning system for the implementation phase control of special projects). Helsinki University of Technology, *CEM Publications 217*, Espoo, Finland.

Koskela, L. (1992). “Application of the new production philosophy to construction.” *Technical report no. 72*, CIFE, Stanford University, Stanford, California, USA

Koskela, L. (2000). “An exploration towards a production theory and its application to construction.” *VTT Publications 408.* Espoo, VTT Building Technology, 296 p.

Koskela, L. (2004). “Making-Do – The Eighth Category of Waste.” *12th Annual IGLC Conference*, Denmark.

Koskenvesa, A. (1989). “Ratu-tuotantotiedoston tiedonkeruun kehittäminen.” (Developing the data collection of Ratu production files). Helsinki University of Technology, *Construction Economy and Management*. Espoo, Finland.

Koskenvesa, A. and Koskela, L. (2005). “Introducing Last Planner: Finnish Experiences.” *Proc., CIB Symposium*, Helsinki, Finland.

Lahdenperä, P. (1995). “Reorganizing the building process, the holistic approach.” VTT Building Technology. Tampere, Finland.

Lavender, S. (1996). “Management for the Construction Industry.” Longman, Harlow.

Lee, S-H., Diekmann, J., Songer, A. & Brown, H. (1999). “Identifying waste: Applications of construction process analysis.” *Proceedings of the 9th IGLC Conference.* Berkeley, USA.

Liker, J. K. (2004). *The Toyota Way – 14 management principles from the world’s greatest manufacturer*. McGraw-Hill, New York, USA

Lindfors, C. 2003. “Process Oriented Information Management in Construction.” Royal Institute of Technology. Stockholm, Sweden.

Lutz, J.& Gabrielsson, E. (2002). “Byggsektorns struktur och utvecklingsbehov.” Byggkomissionen, Sweden.

Metod och Data. (1972). “Swedish Construction Production Data.”

Mäki, T. (2008) "Ratu-tiedoston käyttö rakennustyömaan tuotannonsuunnittelussa." (Using Ratu-production database in production planning on work sites). HY:n käyttäytymistieteellinen tiedekunta, kasvatustieteen laitos. Helsinki, Finland.

Naoum, S. (2001). "People & Organisational management in Construction." Thomas Telford Publishing, London, UK.

Nylén, K-O. (1999). "Civil Works – Unique projects or repeatable process?" The Royal Institute of Technology. Stockholm Sweden.

Olomolayie, P., Jayawardane, A., & Harris, F. (1998). "Construction Poductivity Management." Longman, Harlow.

Osipova, E & Atkin, B. (2008). "From project-oriented to process-oriented risk management in construction." *Proceedings BEAR 2008*, 11-15 February: Building Resilience, Kandalama, Sri Lanka.

PMBOK Project Management Body of Knowledge. (2000). A Guide to the Project Management Body of Knowledge. Newton Square: *Project Management Institute*. PA, USA , 176 p.

Ratu-database. (2010). Finnish Construction Production Data. www-ratu-hanke.fi

Rojas, E & Aramvareekul, P (2003). "Labor Productivity Drivers and Opportunities in the Construction Industry." *Journal of Management in Engineering*. Volume 19, Issue 2, pp. 78-82.

Sacks, R. (2004). "Towards a Lean Understanding of Resource Allocation in a Multiproject Subcontracting Environment." *Proceedings of the 12th Annual Conference of the IGLC*, Helsingør, Denmark.

Sacks, R. & Harel, M. (2006). "An economic game theory model of subcontractor resource allocation behavior." *Construction Management & Economics*, Vol. 24, No. 8, pp. 869-881.

Salminen, J. (2005). Measuring Performance and Determining Success Factors of Construction Sites. Helsinki University of Technology, *Structural Engineering and Building Technology.* Espoo, 175 p.

Seppänen, O. (2009). "Empirical Research on the success of Production Control in Building Construction Projects". Helsinki University of Technology, *Structural Engineering and Building Technology*. Helsinki, 187 p.

Sorri-Teir, E. & Hämäläinen, S. (1993). Talonrakennustyön tuotantotavan kehitys 1900-luvulla. (The development of production practices in house building in 1900-century). *Ministry of Labour*. Helsinki, Finland.

Stratton, R., (2009). "Critical Chain Project Management – Theory and Practice." *Journal of Project Management and Systems Engineering*, TOC Special Issue, Vol 4, pp. 149-173.

Teicholz, P. (2001). "U.S. Construction Labor Productivity Trends, 1970-1998." *Journal of Construction Engineering and Management*, pp. 427-429.

Thomas, H. & Zavrski, I. "Construction Baseline Productivity: Theory and Practice." *Journal of Construction Engineering and Mgment*, Vol. 125, No. 5, pp. 295-303.

Vennström, A. 2008. "The Construction Client as a Change Agent." Luleå University of Technology. Luleå, Sweden.

Womack, J. P., & Jones, D. T. (1996). Lean thinking. Simon and Schuster, New York, USA